



# Long-Range, Near-Side Angular Correlations in Proton-Proton Interactions in CMS

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**(On behalf of the CMS Collaboration)**

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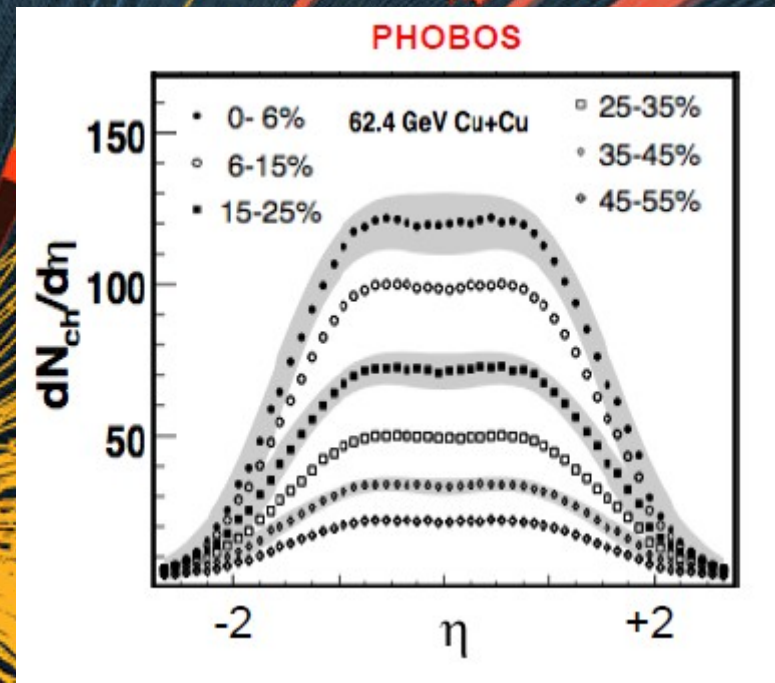
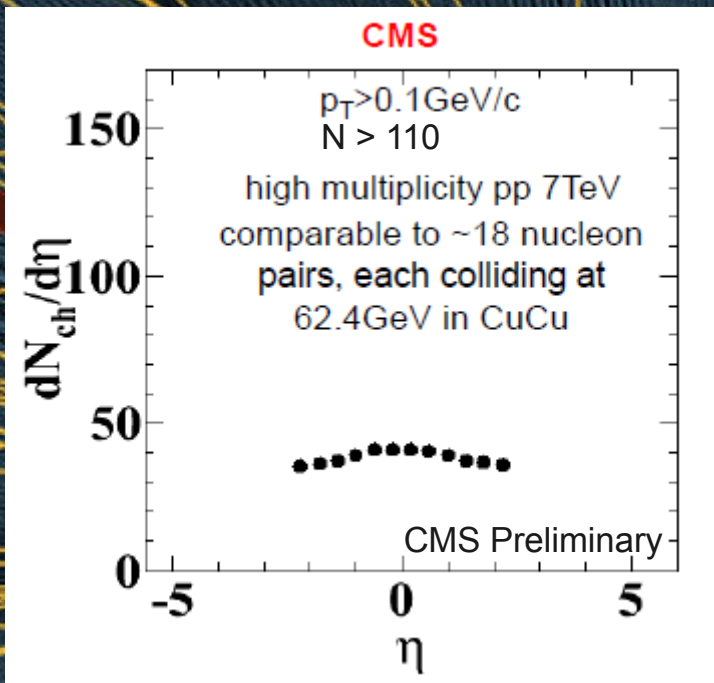


# High Multiplicity Analysis at $\sqrt{s} = 7$ TeV



CMS Experiment at the LHC, CERN

Data recorded: 2010-Jul-09 02:25:58.839811 GMT(04:25:58 CEST)



Large multiplicities observed in 7 TeV data  
 → Detailed studies of the properties of these events

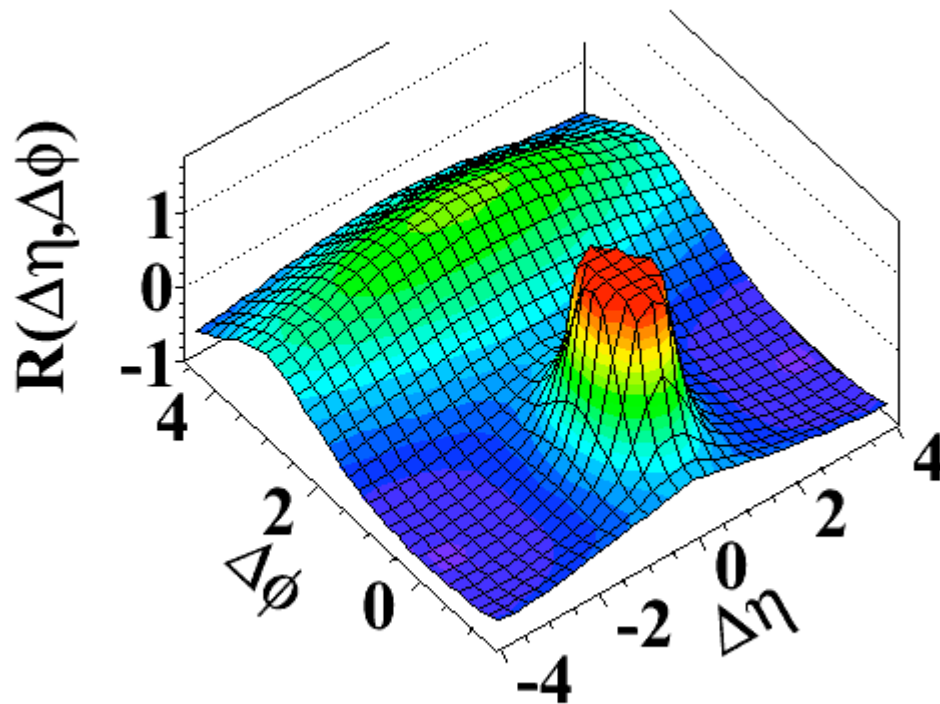
The particle densities in the high multiplicity events of proton-proton collisions at 7TeV begin to approach those in high-energy collisions of nuclei such as Copper  
 → Benchmark / reference for Heavy Ion run

# Two Particle Correlation at High Multiplicity

**Intermediate  $p_T$  :  $1 < p_T < 3$  GeV/c**

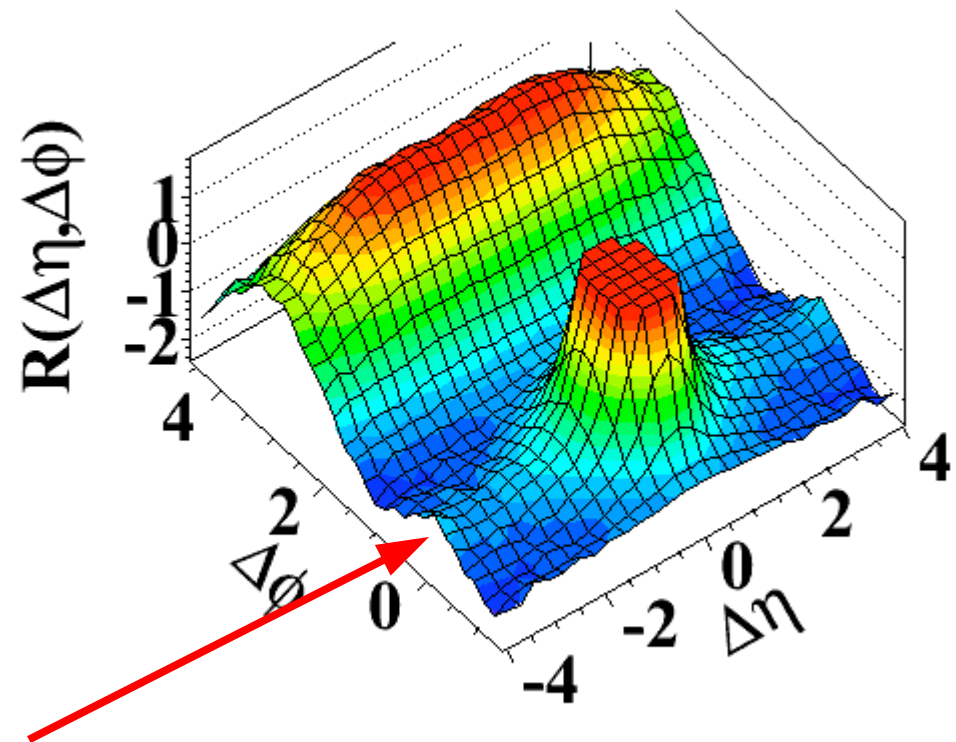
**MinBias**

(b) MinBias,  $1.0 \text{ GeV/c} < p_T < 3.0 \text{ GeV/c}$



**High Multiplicity:  $N > 110$**

(d)  $N > 110$ ,  $1.0 \text{ GeV/c} < p_T < 3.0 \text{ GeV/c}$



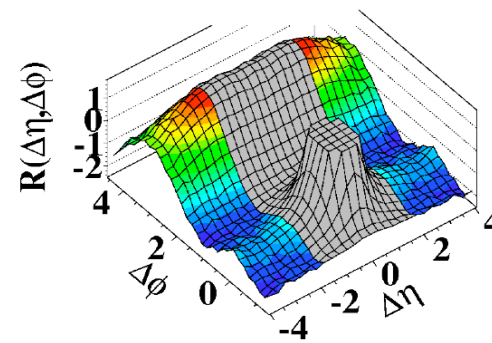
→ **Observation of a Long-Range, Near-Side angular correlations at high multiplicity in pp events at intermediate  $p_T$  (Ridge at  $\Delta\phi \sim 0$ )**





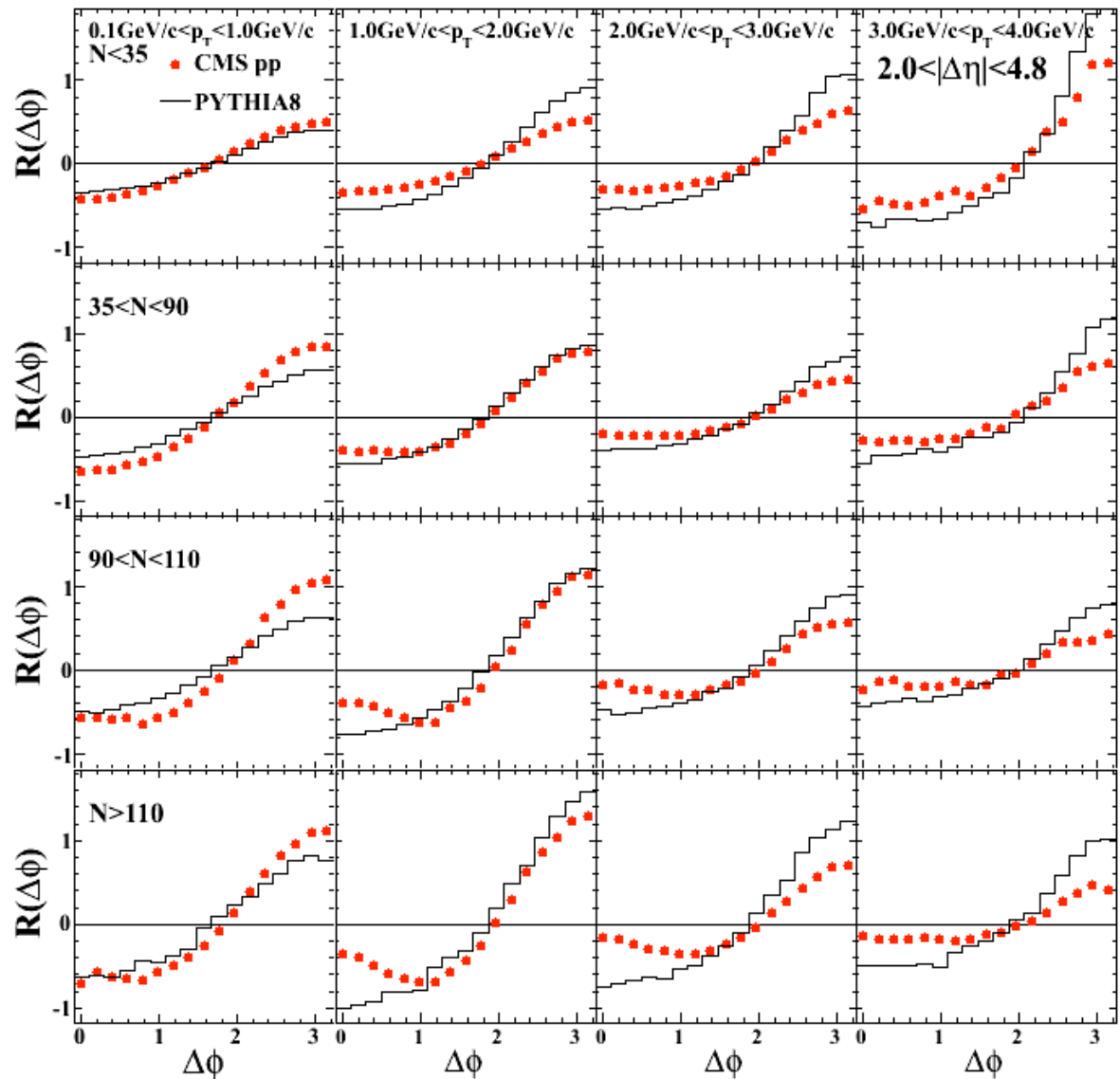
# Multiplicity and $p_T$ dependences

(d)  $N > 110, 1.0 \text{ GeV}/c < p_T < 3.0 \text{ GeV}/c$



$p_T$  range

Multiplicity



→ Study dependence on  $p_T$  and multiplicity for  $2 < |\Delta\eta| < 4.8$  for  $R(\Delta\phi)$  :

$$R(\Delta\phi) = \left\langle (N-1) \frac{\int_2^{4.8} S_N(\Delta\eta, \Delta\phi) d\Delta\eta}{\int_2^{4.8} B_N(\Delta\eta, \Delta\phi) d\Delta\eta} - 1 \right\rangle_N$$

“Ridge” maximal for high multiplicity and intermediate  $p_T$  :  $1 < p_T < 3 \text{ eV}/c$

“Ridge” not reproduced by PYTHIA 8



# Quantifying the “Ridge”: Associated Yield

**Associated yield:  
Extra correlated multiplicity  
per particle**

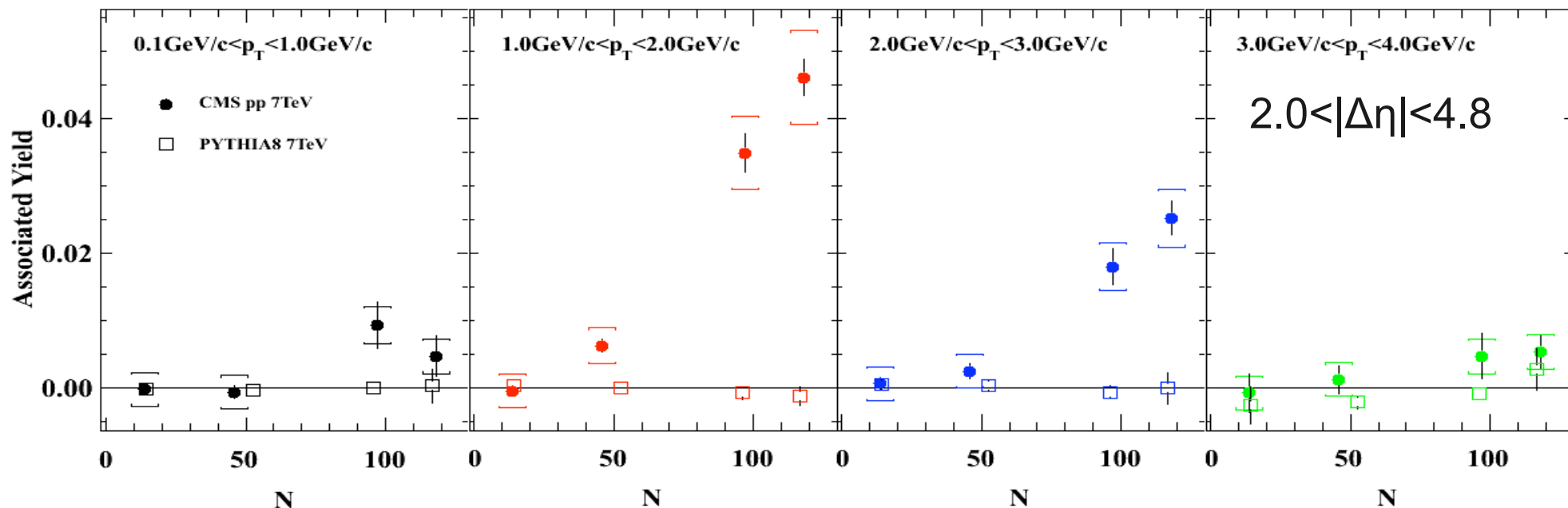
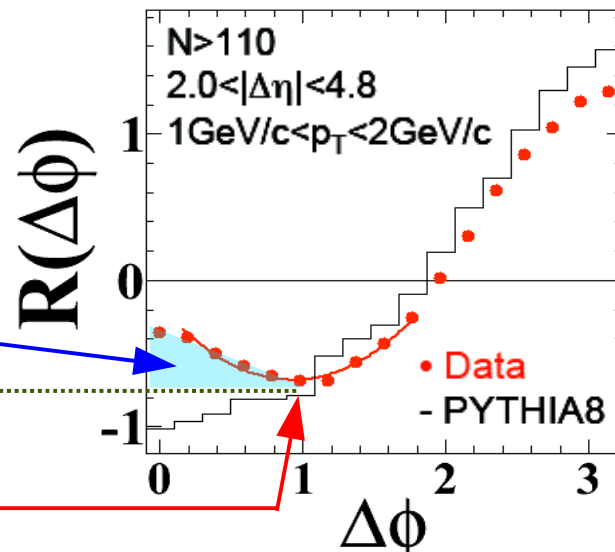
→ **Zero Yield At Minimum (ZYAM) :**

→ **ZYAM = 0 if no “Ridge”**

Integral  
between  
 $\Delta\phi=0$  and  
minimum

Offset

Minimum



→ **Associated yield grows with increasing multiplicity**

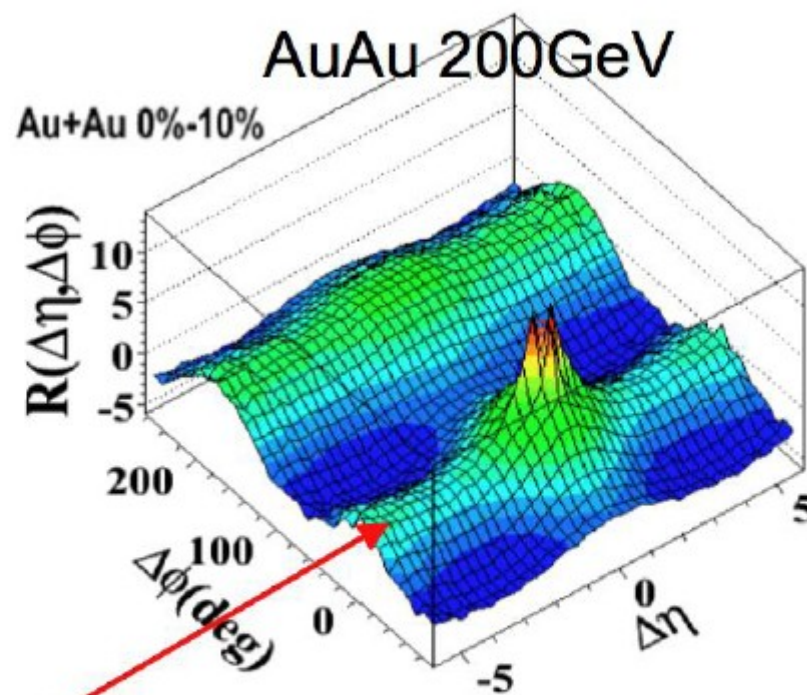
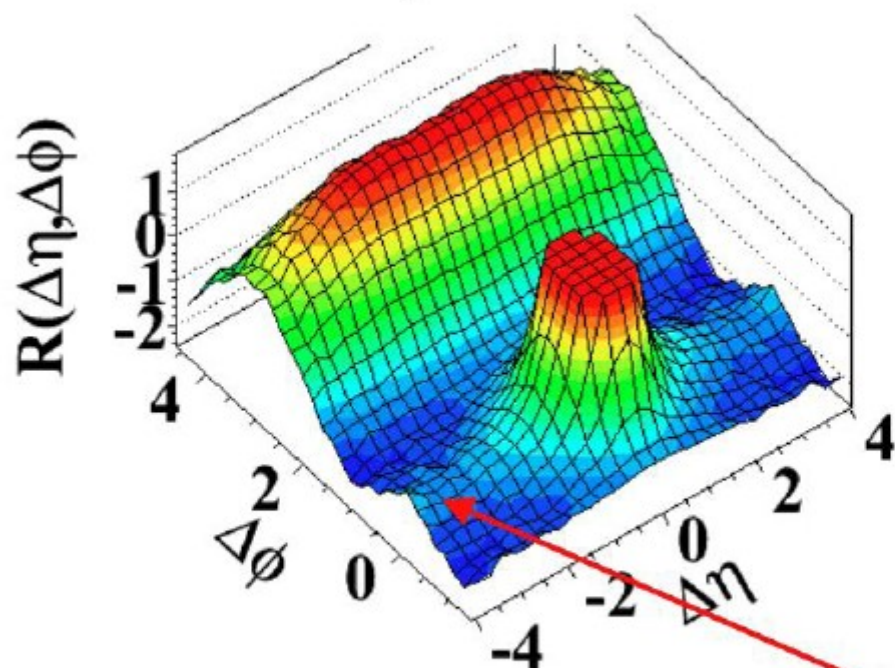
→ **Maximum for  $1 < p_T < 2 \text{ GeV/c}$**



**This is the first observation of such a long-range, near-side feature in two-particle correlation functions in pp or pp collisions.**

It is a small effect, however, very interesting. Although there are also differences, it resembles a similar feature observed at RHIC that was interpreted as being due to the hot and dense matter formed in relativistic heavy ion collisions

(d)  $N > 110, 1.0 \text{ GeV}/c < p_T < 3.0 \text{ GeV}/c$



Similar "ridge" in high multiplicity pp  
(even similar  $p_T$  dependence)

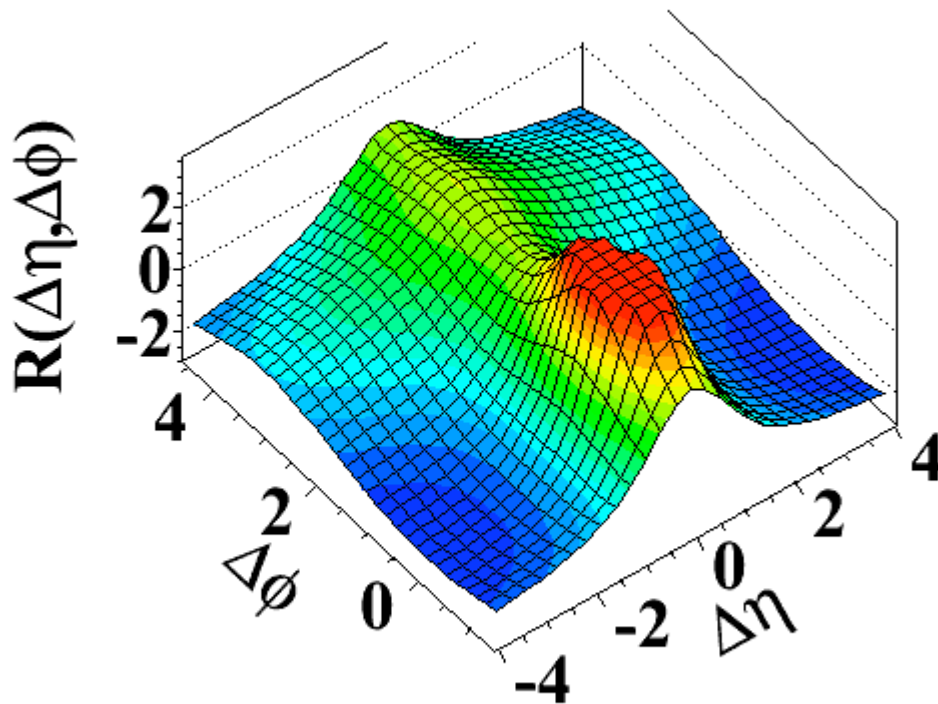
# High Multiplicity Results

**Inclusive  $p_T$  :  $p_T > 0.1$  GeV/c**

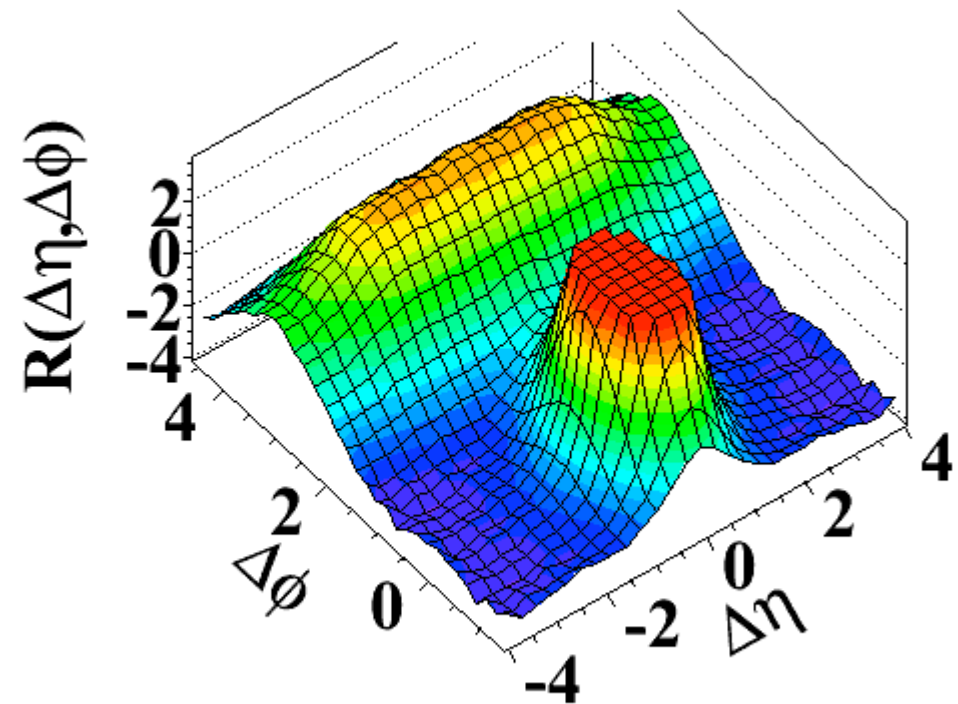
**MinBias**

**High Multiplicity:  $N > 110$**

(a) MinBias,  $p_T > 0.1$  GeV/c



(c)  $N > 110$ ,  $p_T > 0.1$  GeV/c



- Jet peak/away-side correlations enhanced at high multiplicity
- Abundant jet production in high multiplicity sample

→ **Cut-off dominant peak at  $(\Delta\eta, \Delta\phi) \approx (0,0)$  to better see details !**

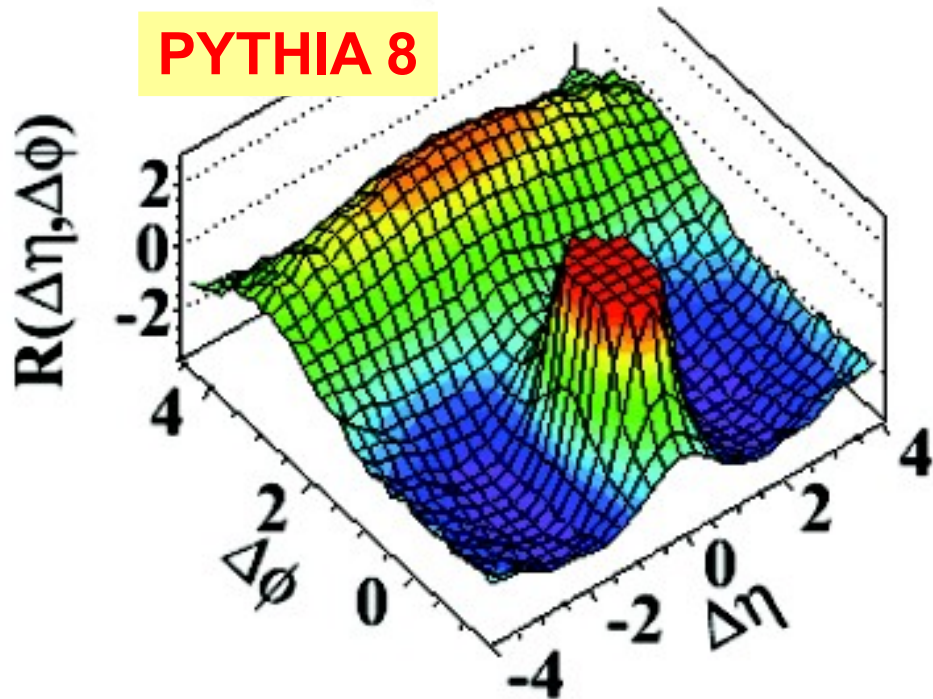


# High Multiplicity Results

Intermediate  $p_T$  :  $1 < p_T < 3 \text{ GeV}/c$

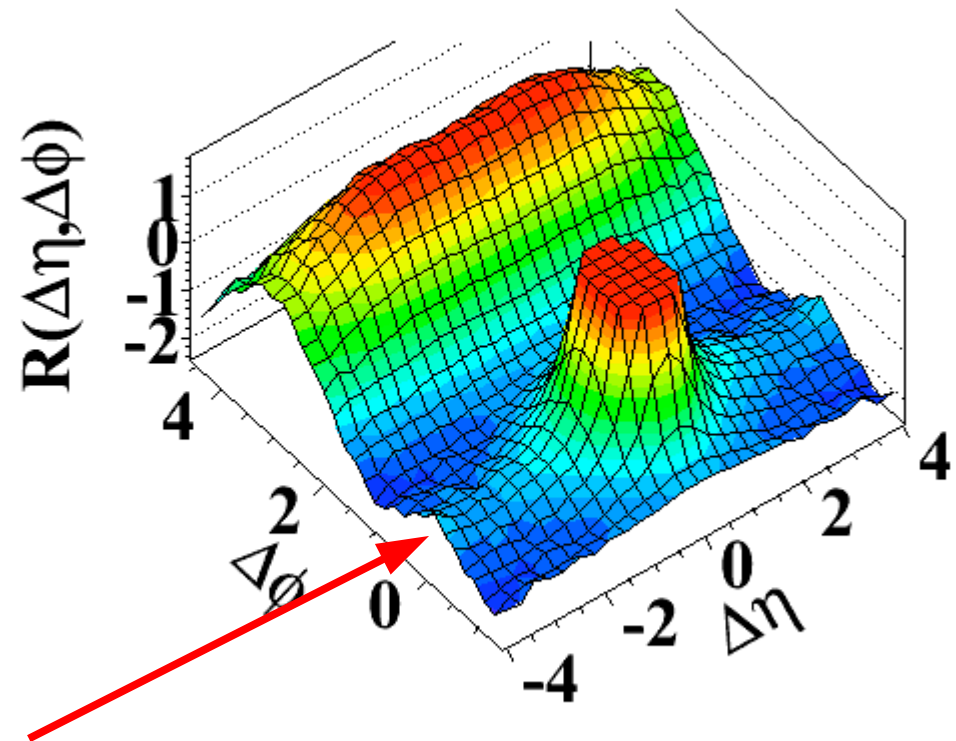
High Multiplicity:  $N > 110$

(d)  $N > 110, 1.0 \text{ GeV}/c < p_T < 3.0 \text{ GeV}/c$



High Multiplicity:  $N > 110$

(d)  $N > 110, 1.0 \text{ GeV}/c < p_T < 3.0 \text{ GeV}/c$



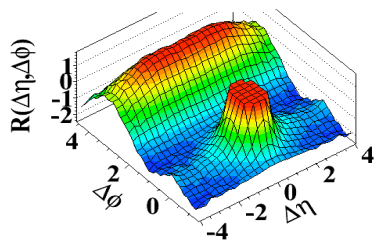
→ Observation of a Long-Range, Near-Side angular correlations at high multiplicity in pp events at intermediate  $p_T$  (Ridge at  $\Delta\phi \sim 0$ )

... not reproduced in PYTHIA 8 (and PYTHIA 6, HERWIG++, madgraph)





## Other pp Event Generators



Analysis Code

Reconstruction

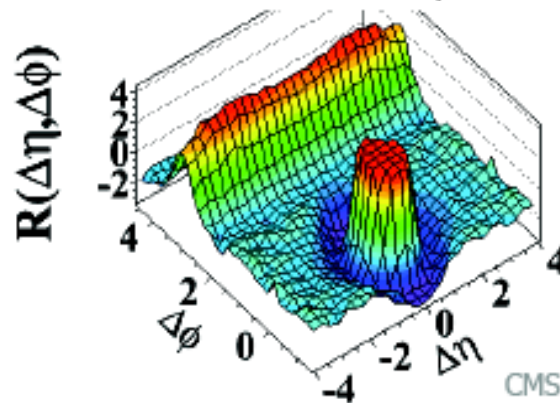
Trigger

Detector

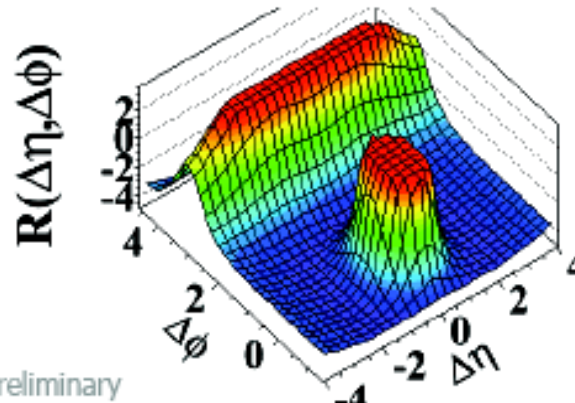
CMS Event

Collision

PYTHIA D6T MinBias,  $N > 70$

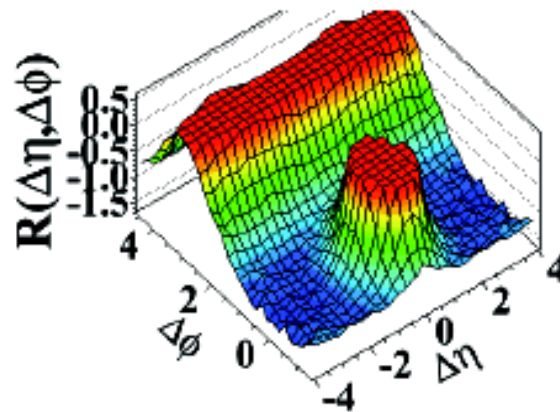


PYTHIA D6T, Dijet 80-120GeV

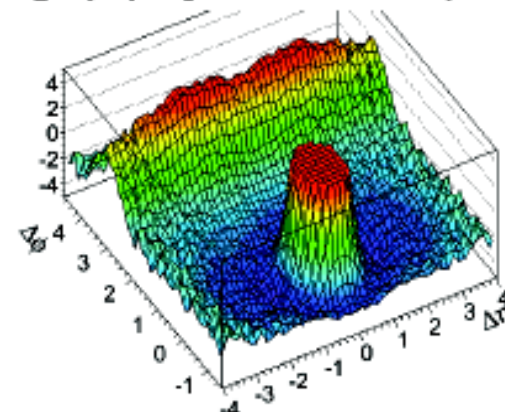


$1 < p_T < 3 \text{ GeV}/c$

HERWIG++,  $N > 110$



Madgraph, Dijet 100-250GeV,  $N > 90$



No ridge effect in these models (with the tunes used)